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ABSTRACT

This review of the literature on computer-assisted instruction (CAI) addresses the following topics: background and scope of CAI; current research on software and learner variables; current research on microcomputers and other delivery systems; meta analyses of the effectiveness of CAI; and methods for evaluating CAI programs. It is concluded that although CAI is generally believed to have positive effects in learning, particularly in the area of computer literacy, current research fails to explain the educational strategies that cause these positive effects to occur. Additionally, computer software evaluation methods and program evaluation methods need to be developed in order to improve the use of educational technology in the classroom. (41 references) (DB)

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RESEARCH BULLETIN

Computer-Assisted Instruction: A Review of the Literature

by

The Department of Testing and Evaluation
Hillsborough County Schools

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F.E.R.C. NOTES ON THIS BULLETIN

Since the microchip has made the cost of computers within the range of most public school district budgets, it is no longer a question whether computers will be used for computer-assisted instruction, but rather what computer-assisted instruction will be used in which manner. This bulletin offers the reader a review of computer-assisted instruction with the belief that it will benefit for those who are not only decision makers but also those who have to implement those decisions which are made.

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Abstract: This review of the literature on Computer-Assisted Instruction has revealed an extensive amount of published material on the extent and nature of the computer's role in education. Among the conclusions which may be drawn from it are as follows: Computer-assisted instruction has experienced a significant growth in this decade; yet, despite general optimism about its potential, there is widespread agreement that much of the available software is of questionable quality, and that better methods are needed for assessing the quality; moreover, although many believe that CAI can have positive effects, research results are often mixed or contradictory, often varying with study type, and there is little empirical data explaining *why* positive results are obtained, or why relationships between study methodology and results occur. This summary concludes with lists of recommendations from the literature.

BACKGROUND AND SCOPE OF CAI

As the literature attests, the growth of computer-assisted instruction in the schools has been rapid. Goodwin et al. (1986) wrote that "An estimated 25% of licensed preschools in the country now have microcomputers, and all preschools are predicted to have access to them by 1989." Buckleitner and Hohmann (1987) wrote that the proportion of U.S. elementary schools having five or more computers jumped from only 7 percent in 1983 to 54 percent in 1985. "At the preschool level, almost half the nation's programs with 20 or more children enrolled have microcomputers, with nearly three-fourths used for educational and recreational activities.... At the elementary and secondary levels, the number of computers in use quadrupled from about 250,000 to over one million between spring 1983 and spring 1985." And Kloosterman, et al (1988) wrote: "...The issue of computer use in elementary school mathematics instruction is not one of 'if' but rather one of 'when' and 'how.' "

This growth in application has been matched by an increase in available products. Dudley-Marling and Owston (1987) pointed out that "By 1985 over 7700 educational software packages were available in the USA and Canada, with up to 2000 packages being added each year by more than 700 educational software producers."

Nor is the growth of computer use restricted to large urban or affluent school districts. Dickey and Kherlopian (1987) were commissioned to survey the use of computers in South Carolina; they developed a Classroom Technology Questionnaire to obtain specific data on the following: (1) the availability of computers in the state; (2) the degree to which they were being used; (3) the purposes for which they were being used; (4) the setting in which they were being used; (5) the preferred applications of computers by teachers; and (6) the types of computer training received by teachers. They concluded that "The notion that rural schools are being left behind by the technological revolution was not supported by the finding that only 27 percent of rural teachers did not have access to computers."

As Bork (1987) stated, this phenomenon is not likely to be ephemeral:

> Indications are that the computer's importance in education will continue to grow. The sudden emergence of a dozen or so magazines concerned with computers in education and the entry of many publishers... into this market show that the movement has gained momentum.

In short, as Kulik (1985), stated, "Educational researchers and developers... are no longer asking whether a computer revolution will occur in education. They are asking instead how it will occur."

This growth in the use of CAI is supported by considerable optimism in the literature concerning its effectiveness. For example, Kulik (1985) wrote:

> ... although CBE has not been uniformly successful in all its guises and at all instructional levels, most CBE programs have had the following positive effects on students: students have learned more and retained more in courses providing assistance from computers; students learned their lessons in less instructional time and liked their classes more when they received computer help; and students developed positive attitudes toward computers when they received help from them in school.

A survey of computer use in schools in three western states (Long, 1985) reported advantages of computer use that are typically cited, including an apparent increase in students' self-esteem, enhanced feelings of success, and increased motivation.

However, such optimism is often tempered with serious questions about the effects of CAI. Goodwin et al. (1986) wrote of the research on the effects of CAI on young children that "Most published literature consists of unsupported claims about a myriad positive effects...

There may be a number of reasons both for the apparent difficulties in installing CAI at the school level, and the obvious lack of unreserved acceptance of it in the literature. Among these reasons are probably the difficulties in implementation due to hardware variables, the lack of teacher preparation, and the poor level of software.

Flouris (1987) stated that "Since many teachers with little or no training began using computers, they have not always acquired the knowledge or the skill to promote meaningful learning in their students." Jolicoeur and Berger (1988) wrote that most teachers do not know how to integrate software into the curriculum and evaluate it. Dickey and Kherlopian (1987) noted that "Of great concern to teacher educators were the data on how few teachers had received formal instruction on using computer in the classroom."

One of the major problems identified (Jolicoeur and Berger, 1988), both in the actual use of computers and in the research into their effects, was the lack of available computer time--there are usually too few computers for all students to have full access to them. Other authors cited possible Hawthorne effects and hardware failure as

difficulties encountered in completing evaluation studies (Ladewig et al. 1987).

But perhaps an even more serious problem, one less susceptible to easy remediation, is the lack of good software: Gonce-Winder and Waldbesser (1987) stated that "It is a commonly held belief in the field that the quality of instructional software is inconsistent and generally poor." And Flouris (1987) pointed out that beyond the problem of lack of teacher preparation "... a more serious problem involves the quality of software. Only a small portion of educational software meets minimal technical and instructional standards." Dudley-Marling and Owston (1987) wrote: "Despite the rapid growth of the software industry, however, concerns over software quality persist."

A problem related by Bork (1987) to the low quality of software is its limited scope. "Many of the examples commonly available fail to reflect the best usage of the computer.... Many of these materials are primarily games." And in fact, a review of the literature conducted by Cawley and Murdock (1987) showed that most software is not only of poor quality, but in most cases simply replicates traditional print-based instruction.

Dudley-Marling and Owston (1987) surveyed published material from the 1980's on educational software. They found early concerns with quality; later papers reported that the use of computers simply to replicate more traditional methods of instruction was being superceded by more use of the unique capabilities of the medium and that overall quality was improving; applications software packages, such as graphics programs, were being used in education. "The consensus of opinion, however, was that although there were some excellent programs available, the overall quality of the instructional software remained relatively poor." They cite a number of specific problems revealed by studies, including poor pedagogy, amateurish programming, and inadequate documentation; limitations in the ability of programs to deal with individual differences; and the predominance of drill and practice programs, which tend to concentrate on lower-level cognitive skills and do not take full advantage of the computer's abilities.

Of course, the lack of good software is not the only problem. Budoff and Hutten (1982) stated that in many areas, "... negative research findings, lack of long-term data, dearth of comparative studies, and other inadequacies preclude a highly positive judgement." They cite a number of reasons for the slow acceptance of CAI at the time of their publication:

-inadequate systems for software production and distribution

-a failure to demonstrate learning advantages and cost effectiveness of CAI

-the absence of a theoretical basis for CAI

-the need to change the traditional role of teachers to accommodate CAI

-the high cost of CAI

All of this may lead one to ask, as Campbell et al. (1987) did, "Should computers be used as part of the instructional process in lieu of well established procedures involving classroom teachers, or should educators forego use of the computer until its worth as a technological teaching tool is clearly proven?"

CURRENT RESEARCH IN CAI

The research background

In order to understand the nature of CAI one has to determine whether it is, or should be, a totally new instructional medium with the ability to deliver unique instruction, or simply a better and faster delivery system for traditional instruction. There is ample discussion of this in the literature. Ross and Anand (1987), for example, suggested that "if the instructional theory underlying a teaching strategy is valid, learning benefits should be independent of the delivery system employed. Should benefits be restricted to CAI, however, one might therefore search for some unique contribution that CAI makes to change the strategy's impact."

Clark (1983) wrote that "media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition." Ross and Anand (1987) responded that "our nutritional health could well be at risk if a delivery truck lacked certain attributes (e.g., a refrigeration unit) needed to deliver products in good condition." In addition, there may be attributes of the computer that enable it to deliver products that are simply not deliverable via other means.

Ross and Anand conducted a review of literature on CAI; they identified a number of ways in which it adapts instruction to individuals and thus delivers instruction superior to that of its predecessors. It does so by individualizing the following factors: the quantity of instructional support, the incentive value of tasks, the contexts of math problems, the types of examples presented, and the exposure time of lesson frames. These various strategies "deliver instructional resources in a manner that would be impossible or impractical...in textbook or lecture presentation."

Garber (1987) claimed that "...the computer does have the power to alter human thinking in ways similar to those of writing and its amplifier the printed book and... school as we know it ought to be the instrument for bringing about this promising change." To support this, he cited literature (Dickson, 1985; Olson, 1985; Salomon and Gardner, 1986) affirming that "certain profound cognitive alterations in pupil thinking are happening now and are likely to become quite pervasive," and "heralding what appears almost certain to be astonishing shifts in perceptions and concept formation abilities among otherwise ordinary learners all seemingly attributable to computer-based learning programs." The computer accesses a new dimension in human thinking and learning, a new dimension which "augments cognition in that it uses the ability of the computer to make available to human senses the actions and structures in subject matter that other media fail to make visible.... The computer itself bears witness to the potentiality of the human mind to extend its own limits beyond boundaries we can barely fathom."

Houston (1985) claimed that "The educational delivery system has remained essentially unchanged for about 500 years. The last significant change (comparable to the computer)...came from an earlier technology, the printing press."

But despite generalizations, we do not know how CAI will make these changes, or will make them. We have not identified the specific factors in CAI that make it superior (Jolicoeur and Berger, 1988). This is where much research is concentrated today, and where it likely will remain in the future.

Thus the role of educational research in the future development of CAI may be at an important juncture. As Kulik (1985) states, "Social scientists have a rare opportunity to measure these effects (of CAI), predict future results, and help control developments at a critical point in the history of education."

Identifying variables in CAI effectiveness

Software and learner variables

Among the most commonly cited factors in the apparent success of CAI in contrast with traditional modes of instruction are such constructs as motivation and confidence. For example, De Blassio and Bell (1981) sought to determine the relationships between students' attitudes toward the use of computers and the following variables: attitudes toward mathematics, attitudes toward the in-

structional setting, achievement in mathematics, achievement in computer programming, intelligence, and sex. They administered attitude surveys, a personal profile and inventory, and an anxiety scale questionnaire, and correlated the resulting data with student records.

Their study concluded that ".... the best predictors of attitude toward using a computer are attitude toward the instructional setting, aptitude for mathematics, and achievement in programming...." and that "Interacting with a computer is usually an unstructured activity that involves some original thinking and rapid responses by the programmer." However, no significant relation was found between attitude toward using the computer and intelligence. Moreover,

> ...the importance of having favorable experience during the initial phases of programming cannot be overemphasized.... Beginning assignments should require the use of simple stored programs with students working in pairs. The first sessions should be closely supervised to provide students with successful, non-threatening experiences.

Seymour et al. (1987) reviewed the literature on the relationship of CAI and motivation. Research in this area is scant until recently, despite the fact that "...willingness to return to computer-based learning tasks is also an important consideration related to the effects of computers." They found more recent research to be more inclusive, yet far from definite as to either the extent to which computers affect motivation or the specific ways in which this happens.

The authors investigated the effects of practice medium (computer vs. pencil and paper), task difficulty, and sex of subject, in an experimental study of fifth and sixth graders (n=139).

A significant relationship was found between computer use, in contrast to the use of pencil-and-paper instruction, and willingness to return to task:

> Results indicated an extremely strong preference for further practice on the microcomputer over a paper/pencil format. This effect was so strong that it left room for only slight variations related to task difficulty and subject gender. Questionnaire responses of subjects also revealed much more favorable attitudes toward the computer than toward the paper/pencil medium.

The computer group thought that their task was easier, that it was more interesting, and that they had been more successful than the control group, although there were no objective differences in the two groups' achievement. "...Merely doing the task on the computer apparently resulted in their thinking that they did well and that it was easier." But there is no evidence that this difference in attitude had an effect on their performance, which affirms earlier research that different presentation media have little effect if the content is the same. This may be a serious argument, not so much against CAI itself, but against using CAI simply to replicate traditional modes of instruction.

Although they conceded that more research is needed into the specific factors underlying the appeal of CAI, "It seems likely that a variety of factors related to a feeling of self-control over the learning medium, such as operation of the machine itself, automatic self-pacing through responding, and immediate responsiveness in a video mode, contributed substantially to the computer's greater appeal."

Swadener and Hannafin (1987) reported the use of a Likert-scale instrument to measure the attitudes toward the use of computers among sixth-graders. The authors placed possible variations in those attitudes in four categories: self-confidence in the use of computers, perceived utility of computers, general attitude toward computers, and sex role in computers. The assessment instrument included 30 items within these categories.

One additional variable that was tested in the study was math achievement. A significant correlation was found between math achievement and confidence in using computers. Little relationship, however, was discovered between gender and perceived utility of computers:

> No differences were found for ratings of statements suggesting that computers are more for boys than for girls, computers are more for girls than for boys, or boys and girls will do equally well on computers. It appears that many elementary school students of both sexes view the opportunities (of using computers) as the domain of the most able irrespective of gender.

However, the authors suggested that misconceptions arise about the computer being primarily for brighter students, and that this effects differences in confidence in using them:

> It seems likely that the same types of misperceptions affecting confidence contribute to these evolving gender differences...significant alterations in the attitudes of both boys and girls occur during the relatively brief three-to-six year period after elementary school. Perhaps attempts to understand more precisely the influences affecting perceptions toward computers in post-elementary settings will yield practical approaches to the design of needed intervention.

In addition to motivation and self-confidence, there are more specific concepts discussed within the contexts of educational psychology and instructional design. For example, Carnes, et al (1987) investigated the role of advance organizers. They began their research with a review of literature on the use of CAI at the secondary level, which provided significant support for the advantages of computers, indicated a frequent shortage of sufficient numbers of computers, but offered little published research on the effects of group size (which becomes critical when the number of computers is limited).

They compared two groups that received computer tutorials in physics, preceded by introductory on-screen materials which differed in content: the experimental group received material that served as an advance organizer for the tutorial, whereas the control group received material which did not serve as an advance organizer. A second effect was the size of the group using the computer. No significant effects were found between the treatment and control groups; however, an effect was noted for group size. "The results suggest that the rate of learning is increased when students work in groups of three or four as opposed to working alone on tutorial programs.... Students having difficulty mastering certain science concepts benefit from instruction in groups of four around the computer most probably because of interaction with the other students." Science teachers should explore the possible advantages of using computers for small group, rather than individual instruction. These findings, however, are for tutorials only, and may not be generalizable to other types of software.

Post (1987) conducted a review of the literature on the use of CAI in industrial education, followed by an experimental study on the role of a cognitive style variable, field independence/field independence (FID), in the effects of CAI. The study administered a pretest/posttest design and a computer tutorial on circuit design,

and paired findings with the *Group Embedded Figures Test* of FID and an IQ test. The study revealed a relationship between a student's FID and achievement gain using CAI. Moreover, FID was shown to be a better predictor of success with CAI than was IQ.

Much of the variance in the study was not explained by either IQ or FID, leading the author to conclude that "...further research needs to be conducted to explain the variance in student achievement in learning material using CAI."

Flouris (1987), in a review of educational psychology literature pertaining to CAI, cited the following studies and their major emphases: Bruner (1960) emphasized the importance of cognitive strategies; Gagne (1972) emphasized intellectual skills and the application of rules to solve problems; Getzels (1964) and Massilas and Hurst (1978) discussed creative and critical thinking, decision making, and coping skills; Wager (1981) emphasized a tutorial algorithm based on behavioristic models; Gagne and Briggs (1979) suggested a model based on instructional events, internal processes, and specific learning outcomes; few educational psychologists stressed rote learning.

Behavioral psychologists, however, defend the use of computer programs for drill and practice (Dudley-Marling and Owston, 1987); and Garber (1987) expressed a behavioristic perception: "Now we have equipment that can make vividly plain the dependency of a bit of learning on the contiguity of a reinforcer."

Taylor (1987) cited research indicating the usefulness of the following in educational software programs: *adaptive program control* and *advisement* (regular diagnoses, progress reports, and prescriptions); and the variation of type or level of control based upon the student's level (more program control for lower ability students, more learner control for higher ability students) and task type (program control for lower-level tasks, learner control for higher-level tasks). As guidelines for courseware selection, the author suggested not only the above factors, but the *accuracy of the courseware content* and *the consonance of pedagogical approach with the school system's adopted approach*, as well.

Jolicoeur and Berger (1988) found that tutorials are apparently superior to games, for the following reasons: Presenting information in multiple forms increases the likelihood of retrieving it; possession of the underlying conceptual basis for solving a problem increases the likelihood that a student will be able to solve related problems; and learning basic conceptual principles enables a student to solve more complex problems in a hierarchical order. But

they admitted that their research was inconclusive.

They cited a difference between *memorized information* and *semantically-encoded information*. The latter is more readily retained. And in contradiction to some other sources (Caffarella, 1987), the authors claimed that a student should be led through a CAI program sequentially. On the question of software evaluation, they claimed that "...teacher recommendations of software do not appear to represent a valid measure indicating *how much students will learn* using a specific educational software program."

There is some interest in the literature in using generic or applicational software (computer programs designed for other than instructional use) for school instruction. These might include database programs, word processors, or graphics or spreadsheet programs. Leonardi and McDonald (1987), for example, recommended using a word-processing program to go beyond teaching writing to teaching thinking. Collis (1988) discussed the use of such programs as word processors, database programs, spreadsheets, graphics programs, and telecommunications in the instruction of social studies, science, language arts, and mathematics.

Much of the research reviewed was conducted within the context of specific populations of learners. These included students in specific content areas, such as mathematics, language arts, or social studies. Other population-directed research was oriented toward special learners and specific grade levels. One area of continued controversy is that of primary and elementary education.

As an annotated bibliography compiled by Woodill and Bernhard seemed to indicate, there are numerous articles and papers dealing with the use of computers in early childhood education. Some of these sources question the use of computers by preschool children, but perhaps an even larger number either support its use or report apparently successful applications. There does not seem to be a definite answer among these papers, articles, and books as to what age children should begin receiving computer-aided instruction.

Buckleitner and Hohmann (1987) suggested the following benefits of the computer with young children: "...by facilitating certain classroom tasks, the computer can release teachers to focus on extending children's thinking, providing varied activities, resolving disputes and offering affection." The authors suggest that computers can have three main effects on young children--to inspire practice of important skills, to stimulate thinking, and to help them use symbols.

Goodwin et al. (1986) stated that there is little solid research on the

effects of computers on young children. "Most published literature consists of unsupported claims about a myriad positive effects.... A considerably smaller proportion of the literature raises concerns about whether or not preschoolers have the requisite skills to use microcomputers beneficially, and about issues such as the quality of available software and the inadequate preparation of teachers on computers."

Moreover, there have been problems in methodology: "The few completed research studies on microcomputer use by preschoolers...have tended to use descriptive or pre-experimental designs." However, true experimental studies have generally revealed small increases in cognitive skills, and sex differences in preference for problem-solving as opposed to drill-and-practice software.

Their study examined different cognitive effects of the microcomputer with three groups--an adult-assisted group, an unassisted group, and a control group not using the computer; as well as the affective effects of computer use on preschoolers' attitudes toward the computer. The affective instrumentation was not empirically validated.

Results on the cognitive measures showed little positive effect in either the adult-assisted or unassisted groups as opposed to the control groups. "This study...lends little support to the many claims that have been made about the positive effects of microcomputer use by preschoolers.... Explicit or implied claims about the appropriateness of these software programs for young children appear overstated."

Lappan and Wilson (1987) concluded the following from reviewing the literature on the use of computers at the elementary level, especially for math instruction:

> Young children can use software and can program in BASIC and LOGO.
>
> Mathematics instruction supplemented by drill-and-practice programs may improve mathematical skills.
>
> Students using microcomputers have positive attitudes toward mathematics.
>
> Children work together effectively on mathematics tasks.

Working in groups of two or three, students instruct each other.

Students work on computer activities longer than other activities and talk more about the task.

Using the microcomputer to teach mathematics is enhanced by teacher direction.

The authors concluded that "Although no studies show a detrimental effect, results suggest that practice may not be the most efficient use of a limited supply of computers."

Kloosterman et al. (1988) conducted a review of literature on the extent and variety of CAI in mathematics at the elementary school level. Many reports and studies from 1980 to 1985 recommended the use of CAI in mathematics education, and many of the later sources, between 1986 and 1987, showed a wide divergence in the degree and type of CAI used in elementary schools. A number of different kinds of programs were cited, including drill and practice, tutorial, simulation, and problem-solving programs:

While drill and practice is the most common type of software used in teaching elementary school mathematics, tutorial, simulation, and problem-solving software are also used.... In general, simulation and problem-solving software force students into much more complex thought than is necessary for drill and practice programs.

The authors also surveyed elementary school principals in a Midwestern state on the impact of computer use in mathematics instruction. An instrument was designed for this, validated and mailed. For two different grade level ranges, K-2 and 3-5, it asked the following question: *How many minutes per week would an average pupil use the computer (alone or in a small group)* to practice previously learned material; to learn new information; to learn by way of a computer simulation; or to attempt to develop problem-solving or higher level thinking skills. Response options ranged from "not at all" to "more than 120 minutes." The study found the following:

While students did not often use computers to learn new material at either of the grade level categories surveyed, they used them significantly more often in grades 3-5 than in grades

> K-2.... Software quality, often thought to be a barrier to computer utilization, was rarely noted as a problem in the comments section of the questionnaire.

They concluded that: "It is probable that some students are using computers to learn mathematics quite frequently while others are probably using computers infrequently if *at all.*" *Computers are* available in most schools surveyed; they are being used to teach material that was usually presented in the past solely by printed matter; they are being used more in intermediate than in primary grades, but they are being used, at least for drill and practice, in a majority of the primary classrooms as well.

Campbell et al. (1987) conducted a study comparing the effects of CAI and traditional print methods, both for drill and practice, among third-grade students of math. Results of their study indicated that there was no significant effect of CAI. "A larger proportion of the print drill and practice group achieved a mastery level and they were able to do so sooner than students in the CAI group. However, the difference in overall performance...was not statistically significant." The authors acknowledge certain methodological weaknesses and the possible effects of confounding factors in their study.

The most important implications of this study, however, may have been that there are great disparities in available software, and that there is a fundamental difference betweem using CAI to replicate print media and using it to create new forms of instruction.

Ladewig et al. (1987) conducted a study of the use of computers in high school home economics courses, in an attempt to evaluate the use of an applied area (home economics) to reinforce learning of basic skills in math, reading, and language. They concluded that

> ...students exposed to the supplementary activities made significantly greater gains in their knowledge of basic competencies in reading, language, and mathematics.... The fact that a significant positive effect was demonstrated in such a short period of time is noteworthy. Long-term systematic exposure to the basic competencies through applied disciplines may produce even greater effects.

Flouris (1987) listed the major types of software programs available for possible use in social studies as drill and practice, tutorials, simulations, and games. The author suggested that quality software

should reflect pedagogical *and* psychological dimensions, but noted that this is not always the case, and added that simulation type programs are probably the best choices for social studies instruction, because they allow the users to engage in discovery learning. Although Wager (1981) classified instructional games and simulations as the same thing, Flouris contended that some simulations are actually drill and practice exercises "in disguise."

Bailey (1987) listed five types of computer programs for use in social studies instruction: tutorial, drill and practice, simulations, games, and application software such as word processing and database programs. Each of these was linked by this author to a different level of learning in Bloom's cognitive taxonomy, e.g.: a tutorial may be used for development of knowledge and comprehension; a simulation may be more applicable for application-leval skills; games are useful for developing analysis and synthesis; and application software such as a word processor are useful for developing evaluation.

Another important area of research focused on the implications of CAI for learners with disabilities or handicaps. For example, Kulik et al. (1983) wrote that "The effects of computer-based teaching seemed especially clear in studies of disadvantaged and low-aptitude students.... "and Budoff and Hutten (1982) wrote that "...the motivational power of working with the computer offers significant advantages not otherwise available to some special needs students, especially those with a long history of failure with traditional instructional formats such as workbooks."

Cawley and Murdock (1987) discussed some of the implications of CAI for handicapped learners. "What the schools must realize is that the mildly handicapped children and youth of today will live for 50 to 60 years in a milieu in which technology will flourish..." Despite popular notions, efforts to implement technology in teaching handicapped students have been modest to date, and "production far exceeds validation and actual use remains far behind traditional methodologies."

One of the problems is software. A review of the literature by Cawley and Murdock shows that most software is of poor quality and simply replicates traditional print-based instruction. However, special educators are developing their own software and identifying numerous sources of information on the use of technology in special education (which their paper lists), providing evidence that "the special education community is taking affirmative action to improve not only the software but also the application of computer

technology in special education in general."

Among the areas that offer advantages to handicapped learners are communicative and data-entry alternatives to the keyboard, such as touch screens and voice recognition; prosthetic communication devices; the ability to adjust the presentation rate of learning material for learning disabled students; and interactive video.

"Interactive video systems have the potential of becoming one of the most exciting and promising instructional devices to come out of electronic technology." Not only is interactive video capable of offering numerous options for learner control; moreover, it is capable of very realistic simulation of real-life situations. "Determining whether videodisk simulation learning will generalize better than role playing or other forms of simulations is an area that needs to be investigated."

Delivery systems

Most of the previously cited research dealt implicitly with stand-alone microcomputers that use commercially-developed software. The following section reports literature concerning alternative methods, especially the integrated hardware/software delivery systems such as WICAT.

Budoff and Hutten (1982) wrote about CAI at a relatively early stage in its implementation. They discussed some of the differences in computer configuration between stand-alone computers and those that are connected via networks, and offered specific methods for networking. These concepts are important because "The hardware configuration may affect teaching strategy, software choices, system utility, and cost." In addition they identified six modes of delivery of computer-assisted instruction--drill and practice, tutorials, educational games, simulations, problem solving, and computer managed instruction.

Bunderson (1982) briefly reviewed the history of WICAT, of which he was co-founder, and distinguished between "hard" technologies, such as microcomputers, videodiscs, and local and distributed networks; and "soft" technologies, such as computer graphics, speech processing, knowledge-based systems (artificial intelligence), and cognitive science.

Kahn (1986) wrote that although curriculum delivery systems such as WICAT are more powerful and flexible than microcomputers, their initial cost is a major obstacle to their implementation. She discussed some of the implications of the high cost of courseware

development for these systems (e.g. WICAT and CCC are currently leasing their courseware; WICAT has formed a consortium with IBM), as well as the implications of the use of these systems for "looming teacher shortages and culturally changing populations," and provided a brief history of the development of WICAT from a nonprofit corporation to its present position.

One advantage of CCC and NIU over competing systems, the author suggested, is that they can "plug in" to existing stand-alone microcomputers.

Glenn (1988) reported on the use of a WICAT CAI system in a school district in Indiana, as a possible solution to declining SAT scores. This system had received much favorable attention--and was selected for this district--because it had been developed by educators and field-tested in actual school situations before being marketed.

Purchase of the system initially met opposition from teachers, based on the following objections: *the best method to improve student achievement would be to hire more teachers and give them more materials, when in fact the school district was reducing its staff; it was feared that the use of computers would further endanger teachers' jobs; the computer system would take up space needed for other purposes.* Despite this opposition it was purchased and installed in October of 1986.

The effectiveness of the system was evaluated through a re-administration of the SAT after five months, as well as through surveys of student and teacher attitudes. Use of the system seemed to provide gains in student achievement; but surprisingly, these gains were in science and reading, instead of in mathematics. Moreover, students' attitudes toward the use of the system seemed to be positive, and teachers' attitudes, after the initial opposition from many, changed to very positive. Typical comments from the teachers were that the system had benefitted both regular and low-achieving students, and that it had made the teachers more aware of variations in student abilites.

Additional studies of the WICAT system include the following:

Stoneberg (1985) described the use of a WICAT system in New York State, the methodology of its evaluation, and the results of that evaluation. An overview of the WICAT system was provided, including its physical layout and operational features, the software used in the system, and the curriculum delivered by the system.

Section 3 of this paper discussed the evaluation of the system's performance, both in cognitive and affective dimensions, via student achievement test scores and questionnaires of students, teach-

ers, and parents. Detailed data were provided in the report, but the results of the evaluation may be summarized as positive on most of the scales. Surprisingly, the author concluded that the "...improved math achievement was apparently unrelated to student attitudes toward math or computers; student math and computer attitudes vacillated while achievement scores improved."

Olsen et al. (1986) described an experimental comparison of three modes of testing: conventional pencil and paper testing, computer-administered testing, and computerized adaptive testing. An introduction to this study discusses the characteristics of each method, and the possible advantages of computerized adaptive testing over the other two methods. The tests were derived from the item bank of the California Assessment Program, and were administered in school districts that had installed the Plato/WICAT system of computer-assisted instruction.

The results of the study indicated high correlations between the three forms of testing; yet the computerized adaptive test required only about one-fourth of the time needed by either of the other two tests.

Hunt (1987) discussed CAI within the context of instructional design. A number of criteria were offered for evaluating an authoring system, and these criteria were applied to an evaluation of WISE, the authoring system developed by WICAT.

Resta & Rost (1986) discussed the experiences of the Albuquerque school district in implementing (in 1984) and evaluating three integrated learning systems (ILS): WICAT, Dolphin, and CCC. All of these systems were purchased and installed for Chapter 1 instruction in reading, language arts, and mathematics. Among the criteria which were used for the evaluation of these systems were the following: educational content; instructional characteristics; documentation and resource materials; management and record-keeping systems; diagnostic and placement systems; programming capability; technical characteristics (graphics, color, user control, etc.); staffing requirements; training; maintenance/service; costs; educational value; and student and teacher perceptions of value.

Results of the study indicated that during the first year the systems were underused and inappropriately used, thus the students did not experience the curriculum as it was designed. This largely resulted from inadequate lab supervision. However, where there were sufficient data, indications were that the programs were more effective for math than for reading; the various programs differed in their ability to match the district's curriculum; and CCC

and WICAT were more automatic in implementation and in student progress than Dolphin.

They recommended funding of lab operators for CAI systems such as WICAT or CCC; training of teachers in the curriculum content of the systems; and further evaluation of the systems discussed in their report (which evaluation was in progress at the time of publication).

Houston (1986) discussed issues involved in the implementation of CAI and warned of the possible adverse consequences (a "backlash" effect) of premature decisions as to the selection and implementation of CAI; offered a history of WICAT from its days as a non-profit organization, and a detailed description of its research school and its research emphasis. The author offered numerous specific recommendations for the implementation of CAI, and discussed four possible levels of sophistication: Level 1 includes standalone personal computers; level 2 includes personal computers interconnected via a network; level 3 is an integrated system, such as the WICAT system; and level 4 would be a mainframe computer.

Bunderson, et al. (1984), provided a background on videodiscs and the history of a project in which a videodisc was developed by WICAT Systems, and discussed the design and use of videodiscs within the context of educational psychology and learning theory. The authors also extensively discussed the evaluation of videodiscs, and proposed methods which may be relevant for the evaluation of any software.

In addition to traditional computer-assisted instruction, there is the possibility of expanding the range of CAI with peripherals such as interactive video. Mashiter (1988) argued that "The motivational aspect of video in the classroom should not be ignored or dismissed...but should be harnessed so that it is not allowed to be abandoned as a novelty effect, but maximizes the potential of the technology." Two fields of recent research are cited as supporting the use of interactive video, "the so-called constructivist theory of identifying and building upon the existing schema held by the student, and..(research concerning) the variety and flexibility within a student's strategy for meaningful learning."

A major advantage of interactive videodiscs is the potential for use of dual-channel sound to address multilingual audiences or learners at different levels. But there is a problem of software availability in interactive video, a problem which is not likely to be resolved as long as there is a stalemate between software developers

and hardware manufacturers, both unwilling at present to invest the large amounts of money needed to lower hardware costs and provide a variety of software.

GENERAL STUDIES OF CAI

There is a great deal of research of a general nature, concerned neither with special populations nor with program variables, yet still oriented toward the factors that make CAI effective (or in some cases, ineffective). A number of these are meta-analyses. For example, Kulik (1985) conducted a meta-analysis of the findings of twenty years of research on the effectiveness of CAI. The types of computer-based education identified by the author include computer assisted instruction (CAI), computer-managed instruction (CMI), and computer enriched instruction (CEI).

Among the overall findings of this study on the effectiveness of the various kinds of computer programs were that students generally learned more when they received help from computers; students retained this learning longer; they required less instructional time to learn; students liked their classes more; and they developed positive attitudes toward the computer. However, computers did not have positive effects in every area studied. Rather, there were varying effects on different grade levels: The CAI programs almost always produced a positive effect in elementary schools, while CMI programs had much weaker effects. At the high school level, CMI programs had the most positive effects, and CEI had the weakest effects, with CAI having intermediate effects. Data on the findings of this meta-analysis are summarized in three tables of effect sizes.

In addition, there were variations in reported effects relative to study designs: The positive effects of CBE were stronger in published studies; effects were stronger in short studies and weaker in long ones; effects were stronger in more recent studies; effects were stronger when different teachers taught the experimental and control groups.

The author cited a number of possible reasons for differences, including "editorial gatekeeping" (basing of publication decision on size of effect rather than on study quality); the novelty effect (which would enhance the initial effect of CBE on students); and experimental design flaws.

Kulik et al. (1983) reviewed problems in early studies of CAI in an attempt to synthesize findings. The studies of the effectiveness of CAI were usually of two types: box-score studies and meta-analyses. The latter were usually more objective and quantitative. Both kinds of studies tended to confirm the effectiveness of CAI in raising student achievement, especially in elementary schools. The authors cited Vinsonhaleer and Bass (1972); Jamison, Suppes, and Wells (1974); Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975); Hartley (1977); Burns and Bozeman (1981); and Kulik (1981), as examples of box-score or meta-analysis studies of CAI research findings.

The authors conducted a meta-analysis of the literature on the effects of CAI in grades 6-12, eliminating those studies that did not follow such procedures as using a true experimental design. The summary of results of the 51 included studies was reported in effect size.

Results of this meta-analysis included a .32 SD improvement in examination scores; a wide range of effect size between the different studies but no apparent relationship between reported results of studies and the study type used; no significant improvement in retention after 2 to 6 months; significant relationship between treatment and attitude toward computers; and a relationship between CAI use and reduced learning time. "We found...that effects on retention measures were basically positive, but not so clear as effects on measures of immediate performance." Moreover, "We found that the computer had an important positive effect on student attitude."

The authors also noted relationships between study outcomes and year of publication of the studies, manner of publication (whether journal or dissertation), and study duration. With respect to the apparent increase in effect in later studies, the authors suggested that it is probably not a result of research design changes: "It seems more likely that instructional technology has simply been used more appropriately in recent years." They also noted:

> The effects of computer-based teaching seemed especially clear in studies of disadvantaged and low-aptitude students, for example, whereas effects appeared to be much smaller in studies of talented students.... But the relationship was far from statistically significant with the number of studies currently available. The reliability of this and other relationships hinted at in our results must therefore be investigated in further analyses.

Gillingham and Guthrie (1987) compared components of teaching identified by research with findings from a meta-analysis of CAI research, in the belief that "...CBI research and research on teaching could benefit from mutual exchange...most CBI research cannot link its findings to specific instructional components."

The author's study design selected only published papers, and of over 200 articles published since 1980, they selected only 13 for their meta-analysis.

They believed that "An instructional framework is necessary to direct instructional computing research." Such a framework would identify specific components of instruction and relate them to success or failure of CAI. They produced a framework by considering components of instruction. One of the primary components of instruction is teacher/student interaction, and the authors identified the following principals of this interaction: the teacher manages the attention/motivation of the learner; presents new subject matter content and learning strategies to the learner; guides the practice and active involvement of the learner; and assesses student proficiency before, during, and after instruction.

The following aspects of educational software were suggested as being critical to their success at grade levels from 9 to 12: opportunities for problem solving, practice, elaboration, corrective feedback, and success; graphic and visual cues; opportunities to ask questions of the program; learner control of routine options; and immediate feedback. The critical factors of instruction were paired with these aspects of software to produce a model, which was in turn used to assess the 13 studies selected for examination.

They concluded that "Perhaps the most obvious and important result in our synthesis of CBI is the discovery of the paucity of studies that report CBI achievement data. "Of all the published literature on CBI since 1980, most was merely descriptive. "We think...that it is time to press microcomputer researchers in CBI to conduct data-base research.... Until more data is present regarding the components of instruction in CBI, only general and vague claims can be made regarding the effects of CBI on achievement."

This research should not strictly be concerned with whether CBI is superior to traditional methods. Rather, "...a more productive approach may be to determine which of the selected components of instruction can be made more productively provided by computer than by a teacher or by text...components that are difficult or costly in traditional teaching environments, but...effective and efficient in

CBI environments."

Ross and Anand (1987) conducted an experimental treatment in which mathematical word problems were presented to the learner in personal terms. "Verbal math problems featuring abstract, unrealistic, or highly technical contexts may hinder learning by requiring the translation of unfamiliar vocabulary and problem applications." In the adaptive treatment studied in the present research, the computer software varied math problems by expressing them in individual terms, using personal information from a student biographical questionnaire. Other groups in the study received problems in abstract and concrete--but not personalized--contexts.

Results of the study showed a positive reaction to the form of presentation of the personalized context, no gender effects, and marked effects on achievement of the personalized-context group over either of its counterparts. Without better measures, the authors stated, there is no way to assess the specific reasons for this effect, although they suggested that the personalized problems increased interest in the task, that there was greater internal or logical consistency in the material thus presented, and that there was a greater connection between the material and the students' own cognitive schema.

METHODS FOR EVALUATING CAI

Many studies and papers were as concerned with the methods of research in CAI as with the substance of that research. The research methodology is of course intricately related to its findings: For example, the inadequacy of software is related to the difficulty in evaluating the software itself and CAI in general.

According to Taylor (1987), over 10,000 elementary and secondary-level software packages were available at the time of publication, but only about a quarter of them had received adequate evaluation. Because of the complexity of software evaluation, the author recommended reducing the evaluation process to only three factors: objectives, feedback, and learner control. (The author conceded that a review of the literature did not necessarily substantiate the presence of learning objectives as evaluative criteria; but their inclusion was urged nonetheless, because the publication of learning objectives suggests that the courseware designers followed *sound development practice*).

Among the kinds of feedback that might be used in a CAI package are recognition (praise and reward); special enrichment learning

activities; and graphic representation of progress. *Learner control* includes control of content (such as the lesson, sequence, or module) and control of strategy (such as elaboration levels, examples, or practice exercises)--as contrasted with *program control*, in which most of the decisions are made by the instructional designer.

Flouris (1987) asked what kinds of standards are applied for the evaluation of software, and answered that software should be evaluated in terms of specific learning objectives.

Kulik et al. (1983) cited the following problems in early evaluation studies of CAI: studies of individual implementations of CAI were published separately, and they differed in settings, experimental designs, and in the kinds of applications they were studying.

Not only are there problems both in the research design and methodology of past studies and in current software evaluation methods; Jolicoeur and Berger (1988) cited many problems encountered in a specific experimental situation, such as the scarcity of appropriate software and the classroom management problems associated with sending students to a separate computer center to receive their specialized instruction. Moreover, great amounts of variance in the amount and type of computer-aided instruction offered were noted.

Jolicoeur and Berger wrote that much of the early research on CAI was oriented toward the kinds of instruction delivered by large mainframe computers, usually using text-only tutorials, as opposed to the animated colorful packages now commercially available, and urged more research on the latter.

Krajcik et al. (1988) pointed out the following problems that have impeded research studies in the effectiveness of CAI: excessively broad generalizations were reported; inappropriate criterion measures were used; criterion measures were sometimes not specified; the assessed software was less than optimal; and the research questions lacked substantive theoretical bases.

In the belief that CAI can help us to learn how students learn concepts and solve problems, the authors in this study used *structured observations* (videotaping of students using CAI), rather than experimental techniques, to study the following: how students develop certain concepts; how students interact with instructional software; how students solve problems; and how to design and employ more effective software. These structured observations can help to provide direction for future experimental research, the authors noted.

A number of recent papers were concerned with methods for evaluating software, and in some cases recommended their own methods or instrumentation for evaluation. For example, Budoff and Hutten (1982) presented six criteria for evaluating the design quality of instructional software:

-individualized instruction, with immediate and frequent feedback
-presentation of a comprehensive curriculum organized into a hierarchy of skills
-articulation of performance objectives
-measurement of progress by mastery of objectives
-use of diagnostic and prescriptive strategies to place the learner
-a multisensory learning format

They concluded that "As teachers become computer-literate and comfortable with the technology, they will expand the range of applications for the equipment and discover teaching options not currently available in resource rooms."

Caffarella (1987) developed an evaluation form to be used by teachers for assessing the effectiveness of software. The instrument included a number of open-ended questions--primarily concerning such topics as the program goals, the program content, and the intended audience of the program--and numerous Likert-scale questions addressing the same topics as well as others--such as instructional strategies used in the program, program design, appropriate use of computers, program techniques, a cost/benefit analysis, and overall evaluation.

The author stated that because teaching methods differ, the software should use methods that match those of the conventional instruction in the school.

"Newer CBI programs should be using 'artificial intelligence' concepts to monitor student performance and to modify the instruction."

In contrast to Jolicoeur and Berger (1988), this author stated that "one of the major strengths of the computer over other media is the ability to interact with the user.... Each student using a CBI program should get a different sequence of frames that is varied based upon the computer's interaction with the student." But "Most CBI programs make only minimal use of this interactive capability."

According to Gonce-Winder and Waldbesser (1987), recent dis-

cussions of software evaluation procedures have focused on the evaluation forms in common use, and specifically "the extreme variance that exists among them in the naming, variety, and completeness of their components." They listed a number of sources from which such evaluation forms may be obtained.

To improve these forms, their listed components should be standardized. "Such terms as documentation, lesson, quality of graphics, ease of use, and educational value...imply different meanings among the forms." Another problem with the forms is the almost universal reliance on subjective, Likert-type responses and open-ended questions. "Open-ended questions should be omitted from evaluation forms or constrained by requiring the use of clearly-defined terms describing software characteristics."

The following characteristics of good software are suggested: capitalizing on the interactive and individualizing abilities of the computer; slight dependence on text; using pictures where relevant to the instruction; using material with discernible learning objectives and any entertaining features it may possess; instructions for use in short, comprehensive stages; slight dependence on external print material; presentation of material in a coherent instructional context; motivation of continuing student attention; freedom from technical errors; reflection of current and valid curricula; use of databases within the program; immediate and positive feedback; inclusion of diagnosis, prescriptive, and branching features; flexibility for teacher modification of the program; and inclusion of supplementary instructional materials.

The authors' resulting evaluation form is a binary (present/not present) checklist, with two sections--the first addressing the teacher's instructional needs and the second addressing the student's needs. The form differs from others in three respects: It considers the shortage of time normally available for evaluation; it eliminates personal bias by asking only absence/presence questions; it uses a research-based instructional standard.

Dudley-Marling and Owston (1987) noted that "Despite the abundance of opinions regarding the state of educational software, there have been *few objective evaluations* of the current pool of educational software...." They listed a number of software evaluation services, and noted that only a small percentage of the programs evaluated by these services were given very favorable ratings. This is probably not surprising, they added, because any group of subjective observations that are normally distributed will have only a small number that are rated to be exemplary.

What is needed instead is a criterion-based or objective rating method, the York Educational Software Evaluation Scale, which the authors proposed. YESES examines software along four dimensions: pedagogical content, instructional presentation, documentation, and technical adequacy. Software was rated as exemplary, desirable, minimally acceptable, or deficient. Descriptors were provided as criteria for each of the ratings and each of the dimensions.

This scale was used to evaluate 105 software packages, and despite its objectivity, only 5 per cent of the programs were rated exemplary. "Since YESES is a criterion-based and not a comparative scale, the relatively low percentage of exemplary software is a cause for concern." The findings support the pessimistic views of the earlier literature as to the quality of currently available software.

CONCLUSIONS

The literature on CAI yields basically two kinds of conclusions: The first kind reflects on the current state of CAI, or offers general directions; the second kind pertains more to the future, and offers specific d irection for further research or implementation.

The following are some of the conclusions of the first kind, and perhaps provide a framework for those of the second category:

"Teachers can use formal evaluation of educational software to guide their initial screening of software, but their final judgments shoud depend upon their own observations of their students as the students interact with the software." (Dudley-Marling and Owston, 1987).

Development of good software is a group effort. "No one individual can produce interactive material as effectively as a group." (Bork, 1987).

Little knowledge exists as to the specific factors involved in the success of CAI:

> This type of information is important for software developers and teachers to know when producing or selecting educational software. It emphasizes that even when the content of the materials presented in the software appears good, studentswill probably not learn as much if they find the software difficult to operate. They are likely to waste time trying to figure how to

> work the program, rather than focusing their attention on understanding the educational content presented.... It may be that these kinds of features play an important role in the effectiveness of educational software and (it) is therefore important for future studies to relate specific software features with significant learning effects. (Jolicoeur and Berger, 1988).

Seymour et al. (1987) emphasized the motivational qualities of CAI.

Houston (1985) predicted the advent of computer adaptive learning via computer adaptive testing, and stated that "...the introduction of computers should be education-driven, not market-driven."

The following are some of the specific recommendations of the literature:

Bunderson et al. (1984) wrote that we need to better understand how we learn, and to evaluate software within the context of such an understanding.

De Blassio and Bell (1981) offered the following recommendations for evaluation: "When evaluating the effectiveness of computer-related learning environments, the opinions and comments of students are necessary in planning appropriate modifications." They suggested the need for further research in the relationship of the affective domain to CAI. "Computer-related activities should be a definite part of regular classwork, be easy enough to insure success for beginners, emphasize group work and student interaction, and be closely supervised to provide assistance for students who have problems at the terminal."

Kulik (1985) recommended more research into the relationships between results of studies on CAI and the types of study design used.

Flouris (1987), urged "the selection of computer programs that emphasize thinking instead of those which promote rote learning.... the design of computer programs for social studies must take into consideration the needs of learners and teachers. The design must not be dictated by computer technology alone, but it should take into account the nature of the social studies curricular and instructional goals and content, as well as a sound and valid instructional design model...."

Mashiter (1988) recommended the use of interactive video as an important expansion of traditonal CAI.

Leonardi and McDonald (1987) urged that students not have to waste instructional time learning to operate complex software: "...to

require students to write on a system with which they are unfamiliar is to ask them to attend to two learning tasks at once. Such tasks confusion is likely to engender frustration and anxiety, emotions hardly conducive to developing writing enthusiasm."

Gillingham and Guthrie (1987) recommended more connection between research in teaching.

Dudley-Marling and Owston (1987) suggested that formal evaluation should be used with caution: "In the final analysis, the efficacy of a piece of software must be judged according to the response of students to that program and not the predictions of adults."

Jolicoeur and Berger (1988), stated that "to produce optimal learning conditions, educational software must provide students with basic conceptual tools that they can use to build and store more complex concepts." They also recommended an eight-step plan for implementing software in the schools:

1. Specify the overall goals of the implementation procedures
2. Select appropriate software
3. Develop software support materials
4. Randomly assign students to comparable groups
5. Schedule and implement computer time for students
6. Test the students at regular intervals
7. Evaluate the success of the software implementation process
8. Evaluate the success of the software implementation procedures

Krajcik et al. (1988) recommended programs that stimulate thought: "Simulations...can facilitate concept learning that is very difficult to achieve with conventional instructional materials and media.... Such simulations can also help foster problem-solving skills.... Appropriately designed software should allow students to interpret and analyze data and provide opportunities to synthesize, to question, and to apply." The authors also offered the following questions as suggested bases for new research:

> How do a student's knowledge, problem-solving skills and strategies, and logical structures change as a result of interaction with specific software?
>
> How does a student construct and link specific concepts together prior to, during, and following this interaction?
>
> How does such interaction influence student learning behaviors?
>
> How does a student explain discrepant data within the

context of an hypothesis?

How does a student explain basic principles to situations where he must interpret and analyze data?

How do alternative teaching methods using CAI affect learning?

What relationships exist between computer graphics and learner variables?

What does a learner observe when working at a video screen and how is it related to what is perceived?

What is the relationship between the two-dimensional video screen and the worlds of theory and reality?

How does the learner's level of control influence the learning that occurs?

Hunt (1987) concluded that "Teachers...will need to become aware of (and)...(for those who wish to develop courseware) expert in, the science of instructional design and its development."

Garber (1987) had noted in an earlier study that teachers and curriculum supervisors in an Eastern city had no idea about learning changes attributable to the use of CAI. "Not only will teachers who do field research in their own classrooms become knowledgeable about student progress but they will naturally become sensitive to the differential effects on learners of various instructional arrangements of content, media, displays, and so on."

The author urged greater collaboration between teachers and educational researchers in their own classrooms, and offered a research model that involves a team approach with research conducted in the classroom. "The model assumed that a collaboration in which the teacher commands equal status with a university-based researcher and a main office inservice coordinator and focuses on solving an immediate realistic schooling problem would have a high probability of success." In addition, the author recommends a broader team approach, comprising persons from educational psychology, computer-oriented instructional systems design, educational research and measurement, and appropriate curriculum areas.

Wagschal (1984) is quoted in Campbell et al. as saying that "U.S. education has shown remarkable resistance...to new technologies." But this statement probably says less about the slow integration of technology into American education than about a common failure to perceive that probably nothing on the scale of the computer has come about in American history, that one would have to go back before American history, to the invention of movable type in the 1450's, for an adequate comparison (Garber, 1987).

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